Available online at www.sciencedirect.com
ScienceDirect
Procedia Economics and Finance 24 (2015) 172 – 181
Procedia Economics and Finance
www.elsevier.com/locate/procedia

International Conference on Applied Economics. ICOAE 2015. 2-4 July 2015. Kazan. Russia

Impact of cooperation on the R&D activities of Brazilian firms

Alexandre G. de Sousa[a]. Marcelo J. Braga[b]. Leandro F. F. Meyer[c]*

[a]*Instituto de Pesquisa Econômica Aplicada, Brasilia, DF, 70076-900 - Brazil*
[b]*Universidade Federal de Viçosa, Departamento de Economia Rural, Viçosa, MG, 36570-900 – Brazil*
[c]*Universidade Federal Rural da Amazônia, Instituto Sócio-Ambiental e dos Recursos Hídricos, Belém, PA, 66077530 - Brazil*

Abstract

Cooperation between private firms and public research institutes improves knowledge flows between these agents. This study analyses the factors associated with decisions in manufacturing firms on whether to engage in Research and Development (R&D) cooperation activities and then evaluates the effect of such decisions on the performance of these firms. Probit models were used for the estimation of propensity score matching to determine the impact of cooperation on the performance of the firms studied. The source of data was the 2008 Technological Innovation Survey (*Pintec*). The results indicate that cooperation positively influences the rate of success in product innovations.

Selection and/or peer-review under responsibility of the Organizing Committee of ICOAE 2015.
Keywords: Innovation; Cooperation; Propensity Score Matching; Brazil

1. Introduction

In order to stimulate innovative activity, much attention has been given to cooperation agreements on research and development (R&D). These agreements are designed to incorporate mechanisms by which firms can profitably appropriate and protect knowledge flows. Agreements of this kind are therefore interesting objects for economic regulation, which should create appropriate incentives without harming market competition.

* Corresponding author. Tel.: +55 31 3899 2215; fax: +55 31 3899 2219.
E-mail address: mjbraga@ufv.br

2212-5671
Selection and/or peer-review under responsibility of the Organizing Committee of ICOAE 2015.
doi:10.1016/S2212-5671(15)00641-3

R&D cooperation agreements have become a topic of interest to public managers. According to López (2006), most of the funding for R&D in the European Union (EU) is aimed at stimulating cooperation between private firms and public institutions, and among the firms themselves. The underlying logic is that the economic growth and performance of the National Innovation System (NIS) can be positively impacted by improved information flows (spillovers) generated though these cooperative agreements.

In addition to the flows of knowledge and information, Belderbos et al. (2004a) identified three other important reasons for firms to engage in R&D cooperation agreements: sharing of costs and risks; skill sharing or complementarities; and factors related to the absorptive capacity of the firm.

In the first case, cooperation agreements for R&D can be used to determine the rules of sharing costs and risks in initiatives where these are high. Therefore, when costs and risks are serious obstacles to innovation, firms would tend to engage in cooperation agreements for R&D.

In the second case, cooperation agreements for R&D could allow the firms to acquire skills and capabilities held by its partners. The greater the availability of technological know-how internalized by the firms, the greater the possibility that complementarities will benefit both partners in a cooperation agreement for R&D.

Finally, in the third case, as the absorptive capacity of a firm (a factor closely related to knowledge flows and complementarities) denotes its ability to take advantage of the R&D activities of other firms, the higher the absorptive capacity of a firm, the greater the benefits of cooperation agreements for R&D (LÓPEZ, 2006; VEUGELERS and CASSIMAN, 2002).

Given the above rationale, it is important to examine R&D cooperation agreements in order to assess their impact on the performance of innovative firms. In addition, it is vital to elucidate the mechanisms and key factors associated with the firm's decision on whether to participate in R&D cooperation agreements with research institutions and other firms, considering the innovative patterns and technological intensity that characterize distinct industrial sectors.

The use of microdata from the Brazilian Technological Innovation Survey (PINTEC), including 16,371 firms (14,355 of whom belong to the industry sector and 2,016 to the service sector) to estimate the impact of the participation in R&D cooperation agreements on the economic performance of firms is one of the contributions of this study to the industrial organization literature. The analysis of the determinants and impacts of R&D cooperation for each group of technological intensity, as defined by the OECD taxonomy is another contribution of this study. Finally, considering that the Brazilian innovation system is in the early stages of development, this study provides important insights for the Brazilian NIS by showing that R&D cooperation is an important element for the innovative and consequently economic performance of firms.

2. Methodology

2.1. Model specification

In addition to the traditional variables (e.g. sharing of costs and risks, complementarities and absorptive capacity of the firms) that have been shown to affect the decision to cooperate, the model postulates the likelihood of cooperation as a variable dependent on the spillovers. Two variables were defined to specify spillovers: *incoming spillovers* and *appropriability*. The first is measured by the importance given to publicly available information for the innovative process of the firm). The second form of spillover, *appropriability*, can be understood as the control the firm can exert over outgoing spillovers, and is measured by the importance given to multiple strategic methods to control the outflow of commercially sensitive information.

The rationale with regard to *income spillovers* it that the greater these spillovers, the greater the scope of learning resulting from cooperation agreements for R&D and consequently the marginal benefit derived from such agreements. Therefore it is expected that the presence of *incoming spillovers* has a positive effect on the likelihood of cooperation.

The effect of *appropriability* on the likelihood of cooperation is not clear, a priori. On the one hand, a low level of control over *outgoing spillovers* (i.e. low *appropriability*) increases the information flows between firms, and then the *incoming spillovers* that are expected encourage more cooperation for R&D. On the other hand, the incentives for a firm to become a *free- rider* on other firms' investments reduce both the profitability and stability of cooperation agreements.

As regards the other variables in the model, the possibility of *sharing costs and risks* through cooperation is expected to exert a positive effect on the propensity to cooperate for R&D. Similarly, it is expected that the presence of *complementarities* involving technological know-how between firms has a positive effect on the likelihood of cooperation for R&D. Since the benefits resulting from R&D cooperation agreements depend on the *absorptive capacity* of firms, it is expected that the higher the firms' absorption capacity, the greater the returns of cooperation agreements for R&D. In this model, the *intensity of R&D* and the *size of the firm* are included as proxies of the *absorptive capacity*. *Intensity of R&D* and *firm size* positively affect the likelihood that a firm will cooperate for R&D.

In order to capture the industry-specific attributes that are expected to affect the decision to cooperate for R&D, the specification of the model includes measures of *cooperation* and *legal protection* at the industry level.

2.2. Endogeneity

Some of the covariates included in the model have great potential to be endogenous. Endogeneity involving *incoming spillovers*, *appropriability* and *intensity of R&D* is considered in Veugelers and Cassiman (2002). López (2006) considered that the *sharing of costs and risks* could also be endogenous.

The propensity to cooperate for R&D can be correlated with unobserved factors that are systematically related to the explanatory variables. López (2006) mentions factors such as the firm's capacity and quality of management, the selected form of governance of R&D activities, openness to new ideas, the degree to which a firm's knowledge is tacit or explicit, factors affecting accessibility to a technologically intensive setting and the likelihood of repeated interaction with the same partner, and the history and duration of the cooperation agreements.

Another reason for expecting endogeneity is the simultaneity of decisions involving the *spillovers*, the *R&D intensity* and the *sharing of costs and risks*. First, cooperation agreements on R&D can be instrumental in managing external flows of information. This implies that the decision to cooperate can influence incoming spillovers, as well as the level of importance given to strategic methods of appropriation. The simultaneity of the decision is also expected to produce endogeneity involving the intensity of R&D and the decision to cooperate. The intensity of R&D could increase because of cooperation agreements which improve the effectiveness of spending on R&D. Finally, when firms use cooperation agreements to share costs and risks, these agreements could influence the level of importance given to the variables identified as obstacles to innovation (LÓPEZ, 2006).

Determination of the endogenous structure of the model

In their study on the determinants of the R&D cooperation of German firms, Cassiman and Veugelers (2002) considered *appropriability*, *incoming spillovers* and the *intensity of R&D* as a priori endogenous variables. However, when an exogenous variable is treated as endogenous the estimated models lose efficiency, even though the estimates remain consistent.

In order to avoid unnecessary losses of estimator efficiency, in this study we applied a methodology that allows us to identify which of the four possible endogenous variables (*appropriability*, *sharing of costs and risks, incoming spillovers* and *intensity of R&D*) should be instrumented.

The methodology consisted, firstly, in estimating a linear probability model (LPM) through two-stage least squares (2SLS), using the algorithm of Baum et al. (2007). This technique involves testing the endogeneity of the variables under the null hypothesis that the specified regressors cannot be treated as exogenous. If the null hypothesis is not rejected, then a Probit model is estimated; otherwise, the C statistic (also known as GMM distance or Sargan difference) is estimated. Estimation of the C statistic allows for testing the exogeneity of the regressors under the null hypothesis that the regressors analyzed are orthogonal to the errors.

The final model specifies and tests endogenous variables by rejecting the null hypothesis that the regressors specified can be treated as exogenous. It also specifies and tests the variables suspected of endogenicity by not rejecting the null hypothesis of the C statistic.

In order to verify if the instrumental variables are valid, i.e., capable of explaining the instrumented variables and uncorrelated with the error term, the algorithm of Baum et al. (2007) was applied. This algorithm involves the calculation of Hansen's J statistic, estimated under the null hypothesis that the instruments are valid.

If the final model (LPM) actually presents endogenous variables, the next step is to estimate a Probit model for the instrumentalization of these variables.

Probit model with endogenous regressors

When the determination of the endogenous structure of the model indicates that there are no endogenous covariates, a common Probit model can be estimated. However, when there is evidence of endogeneity. the common Probit model cannot be used because the maximum likelihood estimators (ML) of Logit and Probit models are inconsistent when endogenous regressors are present.

This study estimated a Probit model with endogenous regressors which specifies the nonlinearity and endogeneity in its structure.

As in the two-stage least squares method (2SLS), implementation of the Probit model with endogenous regressors requires one or more valid instruments, which do not explain the dependent variable directly, but are correlated with the endogenous regressor. According to Cameron and Trivedi (2009), considering the linear model consisting of the equations (1) and (2), in which $y*$ is a latent dependent variable in the structural equation, representing the innovative firm's decision on whether or not to cooperate, R&D is a vector of endogenous regressors in equation (1). These two variables are modeled as *linear* in the vectors of exogenous variables. Thus:

$y^*_{1i} = y^*_{2i}\beta + x'_{1i}\gamma + u_i$ (1)

$y_{2i} = x'_{1i}\pi_1 + x'_{2i}\pi_2 + V_i$ (2)

where $i = 1......N$; x_1 is a vector of $k_1\times 1$ of exogenous regressors; x_2 is a vector of $k_2\times 1$ of additional instruments that could indirectly impact the decision to cooperate (y_1) and, u_i and v_i are random error terms.

The variable y^* is latent and is not therefore directly observed. The observed binary result is 1 if $y* > 0$, indicating that the firm cooperates for R&D and 0 if ($y* \leq 0$) the firm innovates without cooperating for R&D.

Equation (1) is called *structural* and is the equation of primary interest. Equation (2) is called a *first-stage equation* or equation in *reduced form*. The second equation is estimated to instrumentalize the endogenous regressors, to check the strength of the instruments and overall quality of the fit of the reduced form. The structural model completely specifies the distribution of $y_1{}^*$ and y_2 in equations (1) and (2). Considering the case of a Probit with endogenous regressors, it is assumed that (u_i. v_i) follows a joint normal distribution (CAMERON and TRIVEDI, 2009).

Thus, when the determination of an endogenous model structure indicates the presence of endogenous covariates, the decision to cooperate will be estimated using a Probit model with endogenous regressors, where the unobservable propensity to cooperate for R&D (y^*_1) will be a function of the observed explanatory exogenous variables (x_1), the possibly endogenous explanatory variables (y_2) and the error term (u).

Instruments

The instruments necessary to estimate the Probit models with endogenous regressors comprise the X_2 vector in (2). The vector of instruments includes, at the firm level, the basicness of R&D and the intensity of exportation, and at the industry level, the incoming spillovers, appropriability, intensity of R&D and cost-risk relation.

Kamien and Zang (2000) proposed a model in which the benefit a firm obtains from the incoming spillovers depends on the characteristics of its R&D activity. Firms where the R&D activity is basic are more likely to take advantage of the incoming spillovers. Following this argument, one can expect that the more basic the R&D activity, the greater the score of incoming spillovers. The basicness of R&D is approximated by the importance given to information ensuing from universities and research institutes to the innovation process. When the incoming spillovers are considered an endogenous variable, the basicness of the R&D is included in X_2.

The competitive environment of a firm influences its efforts on strategic protection. The variable *intensity of exportation* is used as a measure of competitiveness in the environment in which the firm operates. The underlying premise is that competition is higher in international than in domestic markets. It is then presumed that only the most efficient firms are able to take advantage of exportation, so that there is self-selection in these markets (MELITZ, 2003). As the international market is considerably dynamic and exportation is a key instrument for the performance of the firm (BERNARD and JENSEN, 1999), the assumption is that the higher the intensity of exportation, the greater the competition. When appropriability is considered an endogenous variable, export intensity is included in X_2.

2.3. Impact of cooperation on firms' performance

Three variables were used to assess the impact of R&D cooperation on the economic performance of the innovative firms: net revenue, total revenue, and value of industrial transformation (VIT). Aschhoff and Schmidt (2008) adopted a similar procedure to analyze the impact of R&D cooperation on the average costs and sales of German companies.

In the procedure adopted in this study, there is a disadvantage associated to the possibility that the impact of R&D cooperation on the economic performance of a firm may not be captured due to an insufficient time interval. However, it is worth noticing that the whole analysis takes only innovative firms into account, so that the performance of cooperative innovative firms is compared with the performance of firms with analogous path dependence. This leads both groups of firms to implement product or process innovations in the same period of analysis.

In addition, the procedure adopted in this study seems suitable for analyzing variables such as the amount expended on internal and external R&D and the percentage of public and private funding for R&D activities from 2006 to 2008.

Propensity Score Matching (PSM) will be employed to evaluate the impact of cooperation for R&D on the performance of innovative firms in the manufacturing sector as a treatment effect. The *propensity score*s used for pairing can be easily calculated through Logit or Probit models. The odds obtained in the analysis of the determinants of R&D cooperation, in different groups of technological intensity and with different types of partners, are then applied for the calculation of the effect of cooperation for R&D. As it is usually simpler to control via *propensity score* than through a large vector, z, of covariates, this method is advantageous. However, it is necessary to assess whether the pairing was actually capable of balancing the distribution of covariates in treated and untreated groups.

To evaluate the quality of pairing, the procedures suggested by Rosenbaum and Rubin (1985) are appropriate indicators to assess the balance of the variables used to calculate propensity scores for R&D cooperation.

2.3. Variable definitions and data sources

This study applies microdata from the 2008 Brazilian Technological Innovation Survey (Pintec), conducted by the Brazilian Institute of Geography and Statistics (IBGE). In the case of the industrial sector, the 2008 Pintec survey presents national and regional indicators of the technological innovation activities of Brazilian companies in the 2006 to 2008 period, which are comparable with information from other countries. The data on the companies' total revenue, net revenue, and value of industrial transformation (VIT), which were taken as measures of performance, were obtained from the 2009 Annual Industrial Research (PIA 2009) also carried out by IBGE. The variables used in the study are defined below:

- *Appropriability*: sum of scores of the importance given to the following strategic methods for the protection of inventions or innovations: secrecy; complexity of design; time advantage over competitors;
- *Basicity of R&D*: sum of scores for the importance given to the following sources of information for the process of innovation: universities; governmental research institutes or non-profit organizations;
- *Complementarity:* importance given to the lack of information on technology as an obstacle to innovation;
- *Cooperation*: variable that assumes a value of 1 if the firm cooperates with suppliers, customers, competitors, commercial laboratories or R&D companies, universities and government research or private non-profit institutes;
- *Cooperation with competitors*: variable that assumes a value of 1 if the firm cooperates with competitors;
- *Cooperation with research institutes*: variable that assumes a value of 1 if the firm cooperates with commercial laboratories or R&D companies, universities and government research or private non-profit institutes;
- *Cooperation with suppliers or consumers*: variable that assumes a value of 1 if the firm cooperates with suppliers or consumers;
- *Cost & Risk*: sum of scores of the importance given to the following obstacles to the process of innovation: high innovation costs; lack of appropriate sources of funding; perception of excessive economic risk;
- *Export intensity*: ratio between the export revenue and total revenue of the firm;
- *Incoming spillovers*: sum of scores of the importance given to the following sources of information for the innovation process: conferences, professional meetings and journals; exhibitions;

- *Appropriability at industry level*: average of appropriability at the industry level;
- *Industry-level cooperation*: average industry level cooperation;
- *Industry level cooperation with research institutes*: average of cooperation with research institutes at the industry level;
- *Industry level cost & risk*: Average cost and risk at the level of industry;
- *Industry level incoming spillovers:* average incoming spillovers at the industry level;
- *Industry level legal protection*: average of legal protection at the level of the industry. The legal protection is the sum of the scores of the following methods of legal protection for inventions or innovations: patents; standard design registration; trademarks; copyright;
- *Industry level R&D intensity*: average intensity of R&D at the industry level;
- *Intensity of R&D:* ratio between expenditure on R&D and total revenue;
- *Firm size*: neperian logarithm of the number of employees;
- *Innovative firm*: dummy variable, which takes a value of 1 if the firm has introduced new products or processes, or has significantly improved them;
- *Net revenues*: gross revenue from the sales of industrial products and services, minus taxes on sales;
- *Total revenue*: gross revenue from the sales of industrial products and services;
- *Value of industrial transformation*: difference between the total revenue and the cost of industrial operations;
- *FOB value of exportation*: value of exportations covering costs and risks up to shipment;
- *Internal R&D expenditure*: value of expenditure on R&D activities carried out by the firm;
- *External R&D expenditure*: value of expenditure on R&D activities carried out by third parties;
- *R&D private funding*: percentage participation of private funding in the total investment in R&D;
- *R&D public funding*: percentage participation of public funding in the total investment in R&D;

3. Results and Discussion

3.1. Determinants of R&D cooperation in manufacturing firms

Table 1 shows the results of the estimated model for the determinants of R&D cooperation. The significance of the Wald test indicates that the estimated model has good quality of fit, which means that the covariates present in the model explain the propensity of the firms investigated to cooperate for R&D. Table 1 also shows the explanatory variables considered endogenous and the instruments included in the model.

Table 1: Determinants of R&D cooperation of manufacturing firms and their marginal effects (ME)-Brazil,2008

	Coefficient	z	p > |z|	ME	z	p > |z|
Appropriability	-0.324***	-2.12	0.001	-0.120***	-2.83	0.002
Costs &Risks	0.252**	1.92	0.027	0.094*	1.43	0.076
Incoming Spillovers	3.326***	14.54	0.000	1.236***	10.67	0.000
Intensity of R&D	0.574	0.86	0.389	0.213	0.88	0.379
Firm size	0.058***	11.19	0.000	0.022***	9.24	0.000
Complementarity	0.108	0.50	0.620	0.040	0.50	0.618
Industry level protection	-0.137	-0.06	0.948	-0.051	-0.06	0.948
Industry level cooperation	-0.039	-0.02	0.985	-0.014	-0.02	0.985
Constant	-2.525	-4.77	0.000			
Wald chi2(8) = 436.83 - N = 747 - Prob > chi2 = 0.0000						
Instrumentalized:	*Incoming spillovers*					
Instruments:	All exogenous variables, plus R&D basicity, intensity of exportation, *incoming spillovers,* appropriability and industry level intensity of R&D and costs & risks.					

Source: research results.

Notes: *significant at 10%; **significant at 5%. ***significant at 1%.

The variables a*ppropriability*, *sharing of costs and risks*, *incoming spillovers* and *firm size* are statistically significant in explaining the propensity to cooperate in such firms. With the exception of the significance of *appropriability*, these results converge with those obtained by López (2006) and Cassiman and Vergelers (2002), who studied the Belgian and Spanish manufacturing industry, respectively. The statistical insignificance of R&D intensity concurs with their results as well.

In López (2006) and Cassiman and Vergelers (2002), *appropriability* has a positive effect on the likelihood that an innovative manufacturing firm will seek cooperation agreements to carry out its R&D activities. Theoretically, however, the effectiveness of the strategies to protect commercially sensitive information does not have a clear effect on the likelihood of cooperation.

On the one hand, the importance given to the strategic methods of protection could demonstrate that a company has learned to control information flows, which increases the likelihood of this company taking advantage of cooperation agreements. However, the importance given to such methods can also express a company's preoccupation with potential free-riders on its R&D efforts. In this case, *appropriability* will have a negative correlation with the likelihood of cooperation for R&D.

Table 1 also shows the marginal effects of the determinants of cooperation on the propensity to cooperate. The *incoming spillovers* present the greatest marginal effect (1.236) on the likelihood of a firm engaging in a cooperation agreement. This presumably happens because the greater the importance given to incoming information flows, the greater the scope of learning from R&D cooperation agreements and, therefore, the greater the marginal benefit from cooperation.

The determinant with the second greatest marginal effect (-0.120) on the decision to cooperate is *appropriability*. As already discussed, the considerable importance given to the use of strategic methods to control information flows may express the firm's concern with regard to free-riding on its R&D efforts. Despite the slight marginal effect, the statistical significance of the determinant *sharing of costs & risks sharing* seems to be related to the lack of external private financing and venture capital investment, in addition to the perception of the high risks of innovative activities.

The significance of the determinant *size* indicates the importance given to the skills and absorptive capacity of firms. The larger the firm, the greater its acquired skills and absorptive capacity and thus the more likely it is to benefit from cooperation for R&D.

Table 2 shows the results of the analysis of the determinants of the R&D cooperation of innovative companies in the manufacturing industry with universities and research institutes. Compared with the context of overall cooperation (Table 1), the variable *sharing of costs and risks* loses significance, while the variables *complementarity* and *industry level legal protection* gain significance.

As in general cooperation and in cooperation with competitors, in the case of universities and research institutes the variable *appropriability* also presents a significant negative effect on the propensity to cooperate. This result reinforces the importance given to information flows, including *incoming spillovers* and concern with a possible free-riding effect.

The positive effect of the *industry level legal protection* in cooperation with universities and research institutes also reinforces the importance given to information flows. A low level of legal protection in an industry can encourage free-riding behavior in investment in R&D of other firms, which explains its positive effect on that decision. Along with the effects of *appropriability* and *incoming spillovers*, the positive effects of the level of legal protection in the industry shows that the activity of cooperation with universities and research institutes is a method of internalization of external flows of knowledge in industries where legal protection is commonly used, and in firms for which information flows and strategic methods of controlling such streams are important.

The analysis of the marginal effects (ME) reported in Table 2 shows that the most important factors determining the propensity to cooperate with universities and research institutes are, respectively, *industry level legal protection*, *appropriability* and *incoming spillovers*.

Company size as well as complementarities are also determining factors of a firm's cooperation with universities and research institutes. This result was expected. It shows that the higher the technological know-how and skills accumulated by a firm, the more likely it is to engage in a cooperation agreement.

These results converge with those obtained by López (2006), with the exception of the positive and significant effect of *appropriability*. This difference reveals a discrepancy in the importance given to strategic methods of control of commercially sensitive information between Brazilian and Spanish firms.

Table 2: Determinants of R&D cooperation of manufacturing firms with universities and research institutes and their marginal effects (ME) – Brazil, 2008

	Coefficient	z	p > |z|	ME	z	p > |z|
Appropriability	-4.126***	-23.20	0.000	-1.646***	-23.00	0.000
Costs & Risks	0.208	1.13	0.257	0.083	1.13	0.257
Incoming Spillovers	0.614***	3.38	0.001	0.245***	3.37	0.001
Intensity of R&D	1.497	1.09	0.274	0.597	1.09	0.274
Firm size - ln(po)	0.158***	4.16	0.000	0.063***	4.19	0.000
Complementarity	0.328**	2.30	0.021	0.131**	2.31	0.021
Industry level protection	4.915**	2.11	0.035	1.960**	2.11	0.035
Industry level cooperation	-1.347	-0.81	0.418	-0.537	-0.81	0.418
Constant	-0.891	-2.64	0.008			
Wald chi2(8) = 814.69 - Prob > chi2 = 0.0000 -N = 747						
Instrumentalized:	Appropriability					
Instruments:	All exogenous variables, plus R&D basicity, intensity of exportation, *incoming spillovers,* appropriability, and industry level intensity of R&D and costs & risks.					

Source: research results.
Notes: *significant at 10%, **significant at 5%, ***significant at 1%.

In summary, *appropriability* had a negative effect on the propensity to cooperate, while *incoming spillovers* had a positive effect, except in cooperation with suppliers and customers. *Sharing of costs and risks* was significant in the general model and in cooperation with suppliers and customers. Firm *size* lost its significance in cooperation with competitors and *complementarities* were significant only in cooperation with suppliers and customers and with universities and research institutes.

Despite being a relevant factor for the generation of *absorptive capacity*, *intensity of R&D* was not a significant factor in the estimated models.

4.2. Impact of R&D cooperation on the performance of processing industry firms

The estimated propensity scores in the Probit models presented and discussed in the previous sections were subsequently used to pair the innovative firms which engaged in cooperation agreements for R&D and those which did not. After the pairing, the performance of cooperating and non-cooperating innovative firms was assessed by calculating the average treatment effect (ATT), considering the variables of interest.

Among the non-observable factors which can influence the propensity to cooperate for R&D, López (2006) mentions management quality and capacity, form of governance of the R&D activities, geographical proximity and accessibility to a technologically intensive area, besides the occurrence of prior R&D agreements, duration of cooperation activities and frequency of interactions with the same partner.

Table 3 presents the estimated monetary impacts of the R&D cooperation of innovative firms with universities and research institutes. Given the significance of the impact on total and net revenues of a firm, the effect on VIT (a variable calculated by the difference between the gross value of production and the cost of industrial production) does not allow us to identify the possible impact of R&D cooperation on production costs.

Table 3: Impact of R&D cooperation with universities or research institutes on the performance of manufacturing firms (selected variables) – Brazil, 2008, R$

Variables	Cooperating	Non-cooperating	Difference	t statistic
Net revenue	1,512,322	629,894	882,428**	2.19
Total revenue	1,737,724	686,681	1,051,043**	2.27
Value of industrial transformation – VIT	629,465	276,758	352,707**	1.99

Source: research results.

Notes: *significant at 10%, **significant at 5%, ***significant at 1%.

Although the study by Aschhoff and Schmidt (2008) differs from the present one in some of the parameters analyzed, their results agree with those presented in Table 5. These authors conclude that, when compared to non-cooperative firms, a larger share of the revenue of innovative firms which engage in cooperation for R&D is due to new products while a larger share of cost reduction is due to process innovation. In particular, Aschhoff and Schmidt (2008) conclude that R&D cooperation with universities and research institutes has a positive effect on the rate of success of firms launching new products on the market, while R&D cooperation with competitors leads to greater cost reductions in innovation processes.

In this study, the positive impact of R&D cooperation with universities and research institutes on the revenues of Brazilian innovative firms is also an indication of an enhanced rate of success in launching new products. Despite the positive effect on firms' net revenues the direct impact of their innovation costs remains inconclusive.

4. Conclusions

Cooperation for R&D among private firms and between these firms and the public sector stimulates the generation and spreading of spillovers between these economic agents and is regarded as essential for the economic growth and enhanced performance of the national innovation system. In addition to information and knowledge flows, the literature has identified three other primary reasons for firms to engage in cooperation agreements for R&D: sharing of costs and risks; complementarities or sharing skills; and factors related to the absorptive capacity of the firm.

The present research investigated the factors associated with the decisions of firms in the Brazilian manufacturing industry to engage in R&D cooperation activities and examined the impact of such decisions on their economic performance.

The results suggest that *appropriability* (as an indication of the importance given to strategic methods of protection of information flows) is an key determinant of the decision to cooperate. The great importance given to *appropriability* reveals firms' concern about free-riding effects on their efforts to research and develop. Thus defined, *appropriability* has a negative effect on the likelihood that a firm will cooperate for R&D. The majoe importance given to information flows in the decision to cooperate for R&D is also revealed by the significance of *incoming spillovers* and *complementarities* as determinants of those decisions.

The significance of the *sharing of costs and risks* determinant could possibly be associated with the lack of outside private funding and venture capital investment, in addition to the perception of high risks associated with the innovative activity. The significance of the *size* variable exposes the importance of the skills and absorptive capacity of firms.

Sharing of costs and risks, *incoming spillovers*, and *complementarities* proved to be relevant in determining the decision on the R&D cooperation of manufacturing firms in the subsector of high technological intensity. Another significant event in the analysis of the R&D cooperation of this group of technological intensity firms is that the intensity of R&D, i.e., the absorptive capacity gained through the efforts to research and develop their own firms was relevant in determining the propensity to cooperate for R&D with competitors and with universities and research institutes.

The impact analysis showed that the R&D cooperation of Brazilian innovative manufacturing firms with universities and research institutes leads to higher rates of success for new products launched by these firms. This indication arises out of the positive impact of the R&D cooperation on the revenues of firms, even though the impact on the cost reduction of innovative processes remained inconclusive. The same impact of the R&D cooperation with universities and research institutes was seen for innovative firms with both high and low intensity in technology.

As R&D cooperation with universities and research institutes generates positive impacts on the economic performance of the manufacturing firms, public investments in basic research and knowledge diffusion aimed at specific sectors, policies encouraging the formation of a venture capital market for funding R&D activities. Action designed to improve the relationship between the public and the private sectors are potentially useful mechanisms for fostering productivity gains and economic growth in the manufacturing industry.

References

ASCHHOFF, B., SCHMIDT, T., 2008, *Empirical evidence on the success of R&D cooperation: Happy together?* Review of Industrial Organization 33, 41-62.

BAUM, C. F., SCHAFFER, M. E., STILLMAN, S, 2007, ivreg2: Stata module for extended instrumental variables/2SLS. GMM and AC/HAC. LIML. and kclass regression. Boston College Department of Economics. Statistical Software Components.

BELDERBOS. R., CARREE, M., DIEDEREN B, LOKSHIN, B., VEUGELERS, R., 2004, *Heterogeneity in R&D cooperation strategies.* International Journal of Industrial Organization 22,1237-63.

BELDERBOS, R, CARREE, M, LOKSHIN, B., 2004, *Cooperative R&D and firm performance.* Research Policy 10, 1477-92.

CAMERON, A. C, TRIVEDI, P. K., 2005, Microeconometrics. Methods and Applications. Cambridge University Press: New York, pp. 1034.

CAMERON. A. C; TRIVEDI, P. K., 2009 Microeconometrics Using Stata. Stata Press: College Station, pp. 692.

CASSIMAN. B., GOLOVKO, E., MARTÍNEZ-ROS, E., 2008, *Innovation. exports and productivity.* International Journal of Industrial Organization 28, 372-76.

CASSIMAN, B., VEUGELERS, R., 2002, *R&D cooperation and spillovers: some empirical evidence from Belgium.* American Economic Review 92, 1169-84.

LÓPEZ, A., 2006, *Determinants of R&D cooperation: Evidence from Spanish manufacturing firms.* International Journal of Industrial Organization 26, 113-36.

MELITZ, M. J., 2003, The *impact of trade on intra-industry reallocations and aggregate industry productivity.* Econometrica 71, 1695-725.

ROSENBAUM, P., RUBIN, D., 1985, *Constructing a Control Group Using Multivariate Matched Sampling Methods that Incorporate the Propensity Score.* The American Statistican 30, 33-8.